INSTRUCTIONS

53

Relative to the

OBSERVATION

OF THE

Enſuing Tranſit of the Planet VENUS
over the SUN's Diſk,

On the 3d of JUNE 1769.

BY THE

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INSTRUCTIONS

Relative to the Obſervation of the enſuing Tranſit of the Planet VENUS over the Sun's Diſk, on the 3d of June 1769. By the Reverend NEVIL MASKELYNE, A. M. F. R. S. Aſtronomer Royal.

THE Tranſit of the Planet Venus over the Sun's Diſk, is a curious Phœnomenon in Aſtronomy, which does not happen above once or twice in a Century. The Firſt which was ever ſeen ſince the Beginning of the World, was that which happened in the Year 1639, and was predicted by Mr. Jeremiah Horrox, an Engliſhman, and obſerved only by him and his Friend Mr. Crabtree, both living near Liverpool. The Second Tranſit of Venus was the late One of 1761, and was predicted by that great Aſtronomer Dr. Halley in 1716, who at the ſame Time pointed out to Aſtronomers a new and important Uſe that might be derived from it, viz. to determine to great Exactneſs the Sun's Parallax, and conſequently his true Diſtance from the Earth, and the Dimenſions of every Part of the Solar Syſtem, provided that correſponding Obſervations were made of it by Aſtronomers in diſtant Places for that Purpoſe. The Theory of the Motions of Venus being not known ſufficiently in Dr. Halley's Time, it turned out that Venus in the laſt Tranſit paſſed over the Sun's Diſk at a much greater Diſtance from his Centre than he had ſuppoſed ſhe would, which very much altered the Circumſtances of the Phænomenon, and rendered it much leſs advantageous for determining the Sun's Parallax than he had hoped for. Moreover, unfortunately, the Aſtronomers who were ſent out by the Engliſh and French Nations to make the proper Obſervations were not all able, through unavoidable Accidents, to reach the intended Places moſt ſuitable for drawing the greateſt Uſe from the Obſervations, or were hindered from making them by bad Weather.

Therefore, though conſiderable Advantages were derived to Aſtronomy from the Obſervations of the laſt Tranſit made by Aſtronomers in various Places, yet we are ſtill to expect to receive the full Benefit which this Phænomenon is capable of affording us, from the enſuing Tranſit, which will happen on the 3d of June 1769; which is as well circumſtanced for the Purpoſe as we can well deſire, and indeed more favourably than the laſt Tranſit was expected by Dr. Halley to be.

But, in order to profit from thoſe favourable Circumſtances, endeavours muſt be uſed to have careful Obſervations made on this Occaſion in as many various and diſtant Places as we can, as well to obviate the Hazard of ſeveral Obſervations being defeated by unfavourable Weather, as to confirm and eſtabliſh the Truth from the Agreement and Concurrence of ſo many different Teſtimonies.

It may be added, that Obſervations of the Tranſit of Venus made in various Places, together with the other Obſervations made there in Conſequence of it, will have another great Uſe in ſettling the Latitudes and Longitudes of the Places, and that even though the Obſervations thro' various Cauſes may not reach that abſolute Preciſion which is required for deducing the aſtronomical Conſequences before ſpoken of.

As many ingenious Perſons who have turned their Minds to aſtronomical, mechanical, or mathematical Subjects, may be ſtationed in various Places where an Obſervation of this Kind would be very valuable, and may at the ſame Time be furniſhed with ſufficient Inſtruments for the Purpoſe, but may be deſirous of having ſome Inſtructions afforded them concerning the peculiar Nature of the Obſervation in Queſtion, and other Attentions to be regarded both previous and ſubſequent thereto, in order to make their Labours uſeful, I ſhall here offer to them a few Hints on this

Subject,

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Subject, which, I hope, may encourage them to exert their utmoſt Endeavours upon the Occaſion, and I heartily wiſh them all poſſible good Fortune and Succeſs. At the ſame Time, I think myſelf happy in thus concurring with the noble Views of the Royal Society, and the generous Encouragement which the Honourable Directors of the Eaſt India Company are pleaſed to afford to the Improvement of Science, by recommending the Obſervation of the Tranſit of Venus in 1769, as they did that in 1761, to their Servants in their Settlements abroad, and thereby promoting Aſtronomy and Geography, on which Navigation ſo greatly depends.

The Planet Venus, intirely diveſted of her Radiancy, will traverſe the Sun's Face from Eaſt to Weſt on the 3d of June 1769, in Form of a round black Spot, and will be ſeen, if the Weather be clear at the Time, to all Places of the Earth where the Sun is up. She will be viſible to ſharp Eyes without a Teleſcope, only defended by the Interpoſition of a dark Glaſs; but will appear much more beautiful, and may be obſerved to much more Advantage, with the Help of a Teleſcope. Here the Precaution of interpoſing a dark Glaſs between the Eye and the Teleſcope is abſolutely neceſſary to be taken, without which the Sight may be deſtroyed, or greatly impaired; but, thus ſhielded, it will be perfectly ſecure from Danger or any Inconvenience. Venus will begin to enter the Sun's Diſk to the North-Eaſt Part of the ſame, reckoning the Point of the Sun's Circumference or Limb neareſt to the North Pole of the World to be the North Point. Her Diameter will ſubtend near a Minute therefore, as that of the Sun is about 31½ Minutes, her Diameter will be about $\frac{1}{32}$d of that of the Sun. She will move a Space of about 4 Minutes or 4 Times her own Diameter in an Hour, along a Line or Chord, which at its neareſt Approach is 10 Minutes Diſtance ftom the Sun's Centre. Thus ſhe will take about 6 Hours and 20 Minutes (excluſive of the Effect of Parallax) to move over the Sun's Diſk, from her firſt making a ſmall Impreſſion in the Limb on the N. E. Point, to her going out of the Sun's Diſk on the N. W. Point, and leaving the Sun's Limb there intire again. The Firſt leaſt viſible Impreſſion made by Venus's inner Limb upon the Sun's Limb is commonly called the Firſt external Contact; though, properly ſpeaking, the true external Contact of Venus, and the Sun's Limb, happens a few Seconds of Time ſooner before the leaſt Particle of Venus has entered upon the Sun.

After this, Venus gradually makes a deeper and deeper Impreſſion or Notch in the Sun's Limb, and in about 9 Minutes Half her Opaque Body will be ſeen upon the Sun's Body eclipſing an equal Part of the ſame, the other half of her body being without the Sun's Diſk, and therefore inviſible; in 9 Minutes more, the whole Body of Venus will be introduced within the Sun's Diſk, and her outer Limb will touch the Sun's Limb internally, or form what is called the Firſt internal Contact.

She will now recede from the Sun's Limb, by approaching nearer to his Centre, and in about 2 H. 52 M. more will be found at the neareſt Diſtance of 10 Minutes from the Centre; ſhe will then recede from the Centre again, and in 2 H. 52 M. more, her outer Limb will touch the Sun's Limb internally on the North Weſt Part of the Sun's Circumference, and form the ſecond internal Contact; ſhe will now be leaving the Sun, and in 9 Minutes her Center will appear upon the Sun's Limb, and about 9 Minutes after that her inner Limb will touch his Limb externally, or make the ſecond external Contact: And the Impreſſion made by her Body in the Sun's Limb being become gradually imperceptible ſhe will go entirely out of the Sun.

The moſt important Obſervations of the Tranſit of Venus are thoſe of the Contacts of her Limbs with the Sun's, particularly the internal Contacts.

The beſt Teleſcopes muſt be uſed that can be procured; refracting Teleſcopes of 15 or 20 Feet, reflecting Teleſcopes of 18 Inches, or 2 Feet Focus, or achromatick Teleſcopes, of a new Conſtruction, of 5 or 10 Feet, with double Object Glaſſes, or thoſe of 3½ Feet with treble Object Glaſſes, being ſuch as are chiefly uſed for the Obſervations of the Eclipſes of Jupiter's Satellites, will be very convenient for this Purpoſe.

The exact Times of the Contacts ſhould be ſet down according to a Clock, regulated by Obſervations of the Sun or fixed Stars made on the Day of the Tranſit, and alſo on ſeveral Days before and after, according as the Weather ſhall permit.

The Obſervation of next Importance after the Contacts, is that of the neareſt Diſtance of Venus from the Sun's Centre, which is beſt done by the new divided Object Glaſs Micrometer fitted to the End, either of a reflecting Teleſcope, or the new achromatick refracting Teſeſcope of 3½ Feet above mentioned; other Diſtances of Venus from the Sun's Centre may alſo have their Uſe. But the Obſervations of the Contacts alone may be ſufficient for the Generality of Obſervers to attend to.

It has been remarked above, that dark Glaſſes ſhould be uſed to defend the Eye from the Intenſity of the Sun's Light. Tranſparent Glaſſes ſmoaked over the Flame of a Candle or Lamp, and applied to the Teleſcope, will give a more diſtinct and agreeable Viſion of the Diſks of the Sun and Venus than any tinged or coloured Glaſſes will do.

Provide ſome Pieces of clear Glaſs, not too thick (the common Crown Glaſs uſed for Windows may do as well as any) cut two of them into equal Rectangles of convenient Lengths, and wipe them clean and dry, and warm them a little by the Fire, if the Weather be cold, to prevent their Cracking when applied to the Flame of the Candle; then draw one of them gently, according to its whole Length, through the Flame, and Part of the Smoke will adhere to the Glaſs; repeat the ſame Operation, only leaving a little Part at one End now untouched; repeat the Operation, leaving a further Part at the ſame End untouched; and ſo each Time leave a further Part at the ſame End untouched, till at laſt you will have tinged the Glaſs with ſeveral Dies, increaſing gradually in Blackneſs from one End to the other; ſmoke the other Glaſs in like Manner, and apply the two Glaſſes one againſt the other, only ſeparated by a rectangular Border cut out of Braſs or Card Paper, the ſmoked Faces being oppoſed to each other, and the deepeſt Tinges of both placed together at the ſame End; and tie the Glaſſes firmly together with waxen Thread; and they are ready for Uſe. The Tinge at one End ſhould be the ſlighteſt poſſible, and at the other End ſo dark that you cannot ſee the Candle through it. By this Contrivance applied between your Eye and the Teleſcope, you will have the Advantage, not only of ſeeing the Sun's Light white, according to its natural Colour, and his Image more diſtinct than through common dark Glaſſes, but alſo of being able to intercept more or leſs of his Light, as you pleaſe, and the Clearneſs or Thickneſs of the Air requires it, by bringing a darker or lighter Part of this combined dark Glaſs before your Eye, which will be a great Convenience at all Times, but particularly when the Brightneſs of the Sun is liable to ſudden Changes from flying Clouds. This dark Glaſs ought to ſlide in a Groove fixed to the Eye End of the Teleſcope, in order to relieve the Obſerver from the unneceſſary Trouble of holding it in his Hand, and, when not uſed, ſhould be kept in a dry Place, or well covered up from the Air, elſe the Moiſture of the Air will penetrate between the Glaſſes, and ſpoil the Smoking. This Point ſhould be examined, and the Glaſſes new ſmoked, if neceſſary, a few Days before the Tranſit.

The Teleſcope will be eaſier managed, if it be ſupported upon a Polar Axis, than by an upright Pillar in the uſual Manner. The ſame End will be anſwered by a Braſs Socket fixed to the horizontal Top of a wooden Stand, under an Angle, equal to the Latitude of the Place, upon which the Teleſcope may be alſo ſupported. If the Axis of this Socket be directed to the elevated Pole, either by a Meridian Line or a magnetic Compaſs (allowing for the Variation) it will then be only neceſſary to turn one of the Screws of the Rack-Work, which governs the Teleſcope, in order to keep the cœleſtial Object conſtantly in the Field of the Teleſcope, notwithſtanding the diurnal Motion.

The wooden Stand of the Teleſcope ſhould reſt upon the Ground, and not upon any wooden Floor, if the Circumſtances of the Place will admit of it. It is abſolutely neceſſary that the Teleſcope ſhould be adjuſted to diſtinct Viſion of the Eye of the Obſerver, previous to Obſervation. This is done by turning the Side Screw one Way or the other in reflecting Teleſcopes; but by ſliding the Eye Tube backwards or forwards in refracting Ones, till you ſee the Object moſt diſtinct. A Mark may be made on the Eye Tube of the refracting Teleſcope, by which it may be always re-adjuſted to the ſame Poſition after any Alteration. There is ſometimes placed on the Side of the Tube of reflecting Teleſcopes, particularly thoſe deſigned to be uſed with Dollond's Micrometer, a ſmall Scale, with a correſponding Vernier; the Teleſcope being adjuſted to diſtinct Viſion, the Diſtance of (o) on the Vernier from (o) on the Scale, which is expreſſed by the Diviſions of the Scale, and the Number of the Stroke of the Vernier, which coincides with a Diviſion of the Scale, is to be noted; whereby the Teleſcope may at any Time be re-adjuſted to Diſtinctneſs for the ſame Eye, after any Alteration, by turning the Side Screw, in order to bring the Vernier to the ſame Point of the Scale. For obſerving the Sun, the Teleſcope ſhould be adjuſted ſo as to ſhew the Sun's Circumference, or rather his Spots, if he has any, with moſt Diſtinctneſs. This ſhould be done, particularly by Way of Precaution, ſome Days before the Tranſit of Venus. For obſerving the Eclipſes of Jupiter's Satellites, and other cœleſtial Phœnomena, the Teleſcope may be conveniently adjuſted, by noting when Jupiter's Limb, or rather his Belts, appear moſt diſtinct.

The Clock muſt be ſet up truly perpendicular, which may be done by making the Sides of the Caſe perpendicular, by means of a Plumb-line; in ſome Clocks this may be done more exactly by bringing the lower End of the Rod of the Pendulum, when at Reſt, over a ſharp Point placed for that Purpoſe, or over the middle Point of a divided Arch, intended to ſhew the Quantity of the Vibration of the Pendulum on each Side of the Perpendicular. Moreover, the Clock muſt be fixed very firm, by ſcrewing the Back of the Caſe to wooden Plugs or iron Hold-faſts, driven in tight between the Joinings of a Stone or Brick Wall, or to an upright maſſy Plank, let two or three Feet into the Ground at the Bottom, and ſupported by inclining Stays on the two Sides. If the Clock be not fixed up firm, it will go very irregular; therefore it muſt not be ſet up againſt any common Wainſcot, but fixed to the Wall itſelf. Some aſtronomical Clocks are made to go 8 Days without winding up, and others a Month. By turning a Handle, a Spring will be brought to act on the Wheels, which will keep them going during the Time of winding up the Weight; theſe Clocks are uſually wound up the contrary Way to that of common ones. They are furniſhed with Gridiron Pendulums, compoſed of Braſs and Steel Rods intermixed, or ſome other equivalent Contrivance, which keeps the Diſtance between the Point of Suſpenſion and the Centre of Oſcillation to be always of the ſame Length; whereby they go nearly at the ſame Rate during all the Viciſſitudes of Heat and Cold.

In making Obſervations of any Kind where the Time is required to be known, catch the Second from the Clock by your Eye a little before the Time, and keep counting on the Seconds by your Ear, while your Eye is applied to the Teleſcope, till the Inſtant of the Obſervation arrives, then note the Minute by the Clock, and write it down, together with the Second at which the Obſervation happened; and laſtly ſet down the Hour. Otherwiſe, begin to count the Seconds by the Ear from the Moment of the Obſervation, till you can ſee the Time ſhewn by the Clock, from which ſubtract the Number of Seconds which you counted, and you will have the Time of the Obſervation according to the Clock. It will be moſt convenient to count up to an even Number of Seconds, as 20, 30, or 40 Seconds, or 1 Minute. If the Obſerver is at ſuch a Diſtance from the Clock that he cannot hear its Beats, he ſhould have an Aſſiſtant to ſtand near the Clock, and with an audible Voice count the Seconds as they ſucceed one another in Order. The ſame End may be anſwered by ſetting an Aſſiſtant Clock which ſwings Seconds, and has a loud Beat, to the Time of the Aſtronomical Clock, and making the Obſervations by its Beats inſtead of thoſe of the other. The Aſtronomical Clock ſhould be regulated to keep mean ſolar Time.

The readieſt Method for occaſional Obſervers to regulate their Clock is by taking equal Altitudes of a fixed Star or the Sun's upper or lower Limb, on each Side of the Meridian: But the nearer theſe Obſervations are made to the prime vertical, or that which paſſes through the Eaſt and Weſt Points of the Horizon, the better, provided the cœleſtial Body be not too near the Horizon.

The Mean of the Times of the equal Altitudes of a Star as ſhewn by the Clock, gives the Time ſhewn by the Clock when the Star paſſes the Meridian. But the Mean of the Times of the equal Altitudes of the ſame Limb of the Sun muſt be corrected by the Equation of correſponding Altitudes, to find the Time of his Centre paſſing the Meridian by the Clock, as will be ſhewn more particularly by-and-by.

Theſe Obſervations ſhould be made frequently, in order to know always the Error of the Clock with reſpect to mean Time, and alſo the daily Rate of its going; but particularly on the Day of the Obſervation of any principal Phænomenon, and for ſome Days before and after.

The moſt exact Inſtruments for obſerving equal Altitudes, are the Aſtronomical Quadrant and the *Equal Altitude* Inſtrument. The former being of general Uſe in the Practice of Aſtronomy, on that Account deſerves the Preference. I ſhall therefore explain here at length the Methods of adjuſting it, and taking Altitudes by it, as well off the Meridian for finding the Time, as on the Meridian for finding the Latitude of the Place, as follows.

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OF THE

ASTRONOMICAL QUADRANT

in taking ALTITUDES.

THE Quadrant, whoſe Uſe I am about to deſcribe, is one of the Conſtruction of Mr. John Bird of 1 Foot Radius: It has two Sets of Diviſions, the inner one of which divides the Quadrant into 90 Parts or Degrees and to every 20 Minutes; and the outer one divides it into 96 Parts, and each of thoſe Parts into 4 Parts; both Sets of Diviſions are numbered ſo as to ſhew Diſtances from the Zenith, and each has its particular Vernier, that of the inner one carries the Subdiviſion to every Minute, and that of the outer one ſubdivides each of the 4 Parts into 32 Parts. Hence a Table may be eaſily made to reduce the Zenith Diſtance given by the exterior Arch into Degrees, Minutes, and Seconds. The Micrometer is common to both, and gives a Number of Minutes and Seconds to be ſubſtracted from the Zenith Diſtance, ſhewn by the Diviſions and Vernier of either Set.

The moveable Teleſcope, which is that uſed in taking Altitudes, turns round about the Centre of the Quadrant, and carries the Micrometer and both Vernier Plates along with it. The Inſtrument is ſupported on a braſs Pedeſtal, which ſtands on 4 Screws, and ends in a Fruſtum of a Cone at Top decreaſing upwards, a hollow Fruſtum of a Cone is exactly fitted to this, and turns ſmoothly upon it, and carries the Quadrant by an *Arm* round about along with it into different Azimuths. Parallel to the Plane of the Quadrant is placed a Level, which is attached to the *Arm*; its Uſe is to adjuſt the Axis of the Pillar perpendicular to the Horizon; this may alſo be done by the Plumb-line independently of the Level.

At a ſmall Diſtance from the Centre of the Quadrant, to the left, in a Line perpendicular to the Radius paſſing thro' the loweſt Point or (o), a fine Point is marked upon the central Plate with a Dart pointing to it; at an equal Diſtance below from the Point (o) likewiſe to the left, ſuch another Point is marked upon the Limb of the Quadrant, with a Dart likewiſe pointing to it. Over the two Points a fine Silver Wire is to be hung from a Notch, and ſtretched by a Weight immerſed in Water to check its Vibrations.

The Plate containing the Notch is bent at right Angles downwards; and on this Part is applied to the Side of the Quadrant by a ſteady Pin, and by two Screws above it, having broad Holes under their Heads. The lower Screw is ſcrewed up, but the upper Screw only ſo much as to force the bent Part of the Plate juſt mentioned, which ſprings, to a due Diſtance from the Side of the Quadrant, in order to bring the Notch into the proper Poſition, that the Plumb-line may hang over and biſect both the Points.

By the Preſſure of the Hand the Notch may be moved a little backwards or forwards, (the lower Screw being eaſed if neceſſary) till the Plumb-line appears to hang at a proper Diſtance from the Limb of the Quadrant, which it ought not to touch, but to approach very near to, as within one or two of its own Diameters, or ſo that the Shadow of the Plumb-line may be viſible on the Limb oppoſite a Side Window, or the Light of a Candle held in a very oblique Poſition, to the Plane of the Quadrant.

Magnifying Glaſſes are provided, included in Tubes, for better diſcerning the Biſection of the Points by the Plumb-line, and alſo others for aſſiſting the Eye in judging more exactly of the Coincidence that is to be made between a Diviſion on the Limb and a Stroke on the Vernier. The Weight of the Plummet ſhould be increaſed by putting Shot into it, till it is as great as the Plumb-line will well bear without breaking.

There is a Screw fixed to the *Arm*, which, for the Sake of Diſtinction, I ſhall call ſimply the *Adjuſting Screw*, which works in a Screw Hole depending upon the Quadrant,

drant, and is of Uſe to turn the Quadrant in the Direction of its own Plane, and conſequently to bring the Radius paſſing thro' the Beginning of the Diviſions to be parallel to the Axis of the Pillar and perpendicular to the Horizon, previous to an Obſervation, as will be explained by-and-by in its proper Place.

I ſhall now proceed to deſcribe the Manner of preparing the Quadrant for making an Obſervation correctly; that is to ſay, of adjuſting its Parts to one another, and of fixing the Whole in a proper Poſition. But as there are ſeveral of theſe Adjuſtments, ſome of which muſt be repeated every Time the Quadrant is uſed, and others require only to be made once for all, I ſhall treat of them ſeparately, and ſhall firſt explain the uſual Proceſs of adjuſting the Inſtrument for Obſervation, together with the Method of making the Obſervations themſelves, and ſhall afterwards deſcribe thoſe particular Adjuſtments ſeparately, which, when once made, give the Obſerver no further Trouble.

Place the braſs Pedeſtal (carrying the Quadrant) upon a Wall or Pillar, or upon a firm wooden Support which itſelf ſtands upon the Heads of ſmall Piles or large Piquets driven into the Ground, or at leaſt on a Stone or Brick Foundation, and not upon any wooden Floor. Place the Plane of the Quadrant parallel to the Line joining two oppoſite Screws of the Pedeſtal, and eaſe one of theſe Screws, and ſcrew up the other as much, till the Bubble of the Level reſts equally between the two Scratches made upon the Glaſs Tube with the Point of a Diamond. Then turn the Quadrant half round upon its Axis of Motion, till the Plane of it is again parallel to the ſame Line of the Screws, and if the Bubble ſtill agrees with the Marks upon the Glaſs, it is well; but, if otherwiſe, eaſe one of the two forementioned Screws of the Pedeſtal, and ſcrew up the other as much, till the Bubble has moved over half the Space by which it differs from the Marks, and note toward which End of the Tube it inclines. Now turn the Quadrant 90° about in Azimuth, till the Plane of it be parallel to the Line of the other two oppoſite Screws, and if the

Bubble does not reſt in the ſame Manner with reſpect to the Marks, as it did before, eaſe one of the Screws juſt mentioned, and ſcrew up the oppoſite one till it does.

Then eaſe the two outer or puſhing Screws, and ſcrew up the middle Screw of thoſe three Adjuſting Screws of the Level which are at that End of the Tube to which the Bubble inclines, till the Bubble reſts equally between the Marks; and the Axis of the Pillar is now ſet nearly perpendicular to the Horizon, and the Level (that is to ſay, the Line which is a Tangent to the middle of the Bubble) is nearly perpendicular to the Axis, and conſequently nearly parallel to the Horizon. This may be called the Rough Adjuſtment. Then turn the Quadrant half round, ſo that the Plane of it may be parallel to the ſame Screws of the Pedeſtal as before; and if the Bubble ſtill reſts equally between the Marks, the Quadrant is adjuſted right in this Poſition; but if the Bubble does not agree with the Marks, eaſe one of the ſame Pair of Screws, and ſcrew up the other, ſo that the Bubble may move over half the Space by which it differs from the Marks, and alter the Screws of the Level in the Manner juſt now deſcribed, till the Bubble reſts equally between the Marks. Turn the Quadrant half round back again; and if the Bubble agrees with the Marks, the Quadrant is rightly adjuſted in this Poſition; if otherwiſe, alter the Screws of the Pedeſtal and Level as before, and repeat the Operation, if neceſſary, till the Bubble agrees with the Marks in both Poſitions of the Quadrant produced by turning it half round.

Now turn the Quadrant 90° about in Azimuth, or into its firſt Poſition, the Plane of the Quadrant being parallel to the Line of the two oppoſite Screws, and note whether the Bubble reſts equally between the Marks; and if it does not, eaſe one of the correſponding Screws of the Pedeſtal, and ſcrew up the other till it does; and the Axis of the Pillar is ſet truly perpendicular to the Horizon: For more Certainty, you may turn the Quadrant half round, and ſee whether the Bubble ſtill agrees with the Marks, which it ought to do equally in theſe two oppoſite Poſitions of the Quadrant, as it did before when the Plane of the Quadrant was placed parallel to the Line of the other two Screws.

Having thus adjuſted the Axis of the Pedeſtal perpendicular to the Horizon, the Quadrant is now ready to be adjuſted for Obſervation.

And in the firſt Place let the Plumb-line be hung on over the Notch, and ſtretched by the Plummet, immerſed in Water, to prevent the Oſcillations which it would otherwiſe acquire from the leaſt Pulſe of Air, and carefully obſerve whether ſo hanging it biſects both the Points; which if it does not, it is to be brought to do, partly by altering the *Adjuſting Screw*, and partly by the Screw which adjuſts the Spring that carries the Notch from which the Plummet hangs, as before deſcribed. This may be done moſt conveniently by firſt altering the *Adjuſting Screw*, if neceſſary, till the Plumb-line is parallel to the Line joining the Points, and then altering the Screw which governs the Notch till the Plumb-line biſects both Points.

Next turn the Plane of the Quadrant about into the Vertical Circle, which the cœleſtial Body will occupy in a few Minutes of Time forward, and ſet the Teleſcope at or near the Zenith Diſtance which you expect it will have in the Obſervation which you are about to make, and obſerve whether the Plumb-line ſtill biſects the lower Point; if it does not, make it ſo to do, by turning the *Adjuſting Screw* alone, and the Radius paſſing through the Beginning of the Diviſions will be ſet truly perpendicular to the Horizon, and conſequently, as the Axis of the Pillar was ſet perpendicular to the Horizon before, the Inſtrument is properly prepared for Obſervation.

Then, if it be the Meridian Zenith Diſtance which is to be obſerved, turn the Quadrant gently about upon its Axis, if neceſſary, ſo that the Star or ☉'s Centre may be always found very near but not quite upon the vertical Wire of the Teleſcope, and turn the Micrometer Screw, ſo as to cauſe the middle horizontal Wire of the Teleſcope to biſect the Star, or be itſelf biſected by the Sun's upper or lower

Limb; and as the Object diminiſhes its Zenith Diſtance in approaching the Meridian, keep turning the Micrometer Screw, ſo that the Wire ſhall always apply itſelf in the ſame Manner to the Object; and when the Object ceaſes to change its Zenith Diſtance, the Quadrant points out the apparent Meridian Zenith Diſtance. It will be ſtill more accurate, if the Obſerver brings the upper or lower Side of the Wire to be a Tangent to the Sun's Limb, and makes an Allowance for the half Breadth of the Wire, which may be found by Obſervations taken from both the upper and lower Limbs of the Sun in this or any other Meridian Tranſit, uſing the Sun's Semidiameter as given in the Nautical Almanac.

The Method hitherto deſcribed is proper for obſerving Meridian Zenith Diſtances before the going of the Clock is known; but after that is found, keep turning the Quadrant about with reſpect to Azimuth, by means of the Screw which is faſtened by a Clamp to the Azimuth Circle, and alter the Zenith Diſtance of the Teleſcope by means of the Micrometer Screw, ſo as always to keep the Object in the ſame Manner applied to the Wire as before directed, till the Clock ſhews the Time at which the Object ſhould paſs the Meridian, and the Quadrant will then point out the apparent Meridian Zenith Diſtance.

A third, and the moſt antient and beſt, but not always the moſt ready and convenient Method of taking Meridian Altitudes, is by bringing the Plane of the Quadrant into the Meridian by means of an exact Meridian Line; for it is evident, that the Zenith Diſtance meaſured, when the Star or Sun's Centre paſſes the vertical Wire, will be the apparent Meridian Zenith Diſtance.

An experienced Obſerver may take the Meridian Zenith Diſtance of one Limb of the Sun, and read it off, and then obſerve that of the other Limb within the Space of two Minutes; the ſecond Obſervation he may read off at his Leiſure.

The Mean of theſe two Obſervations will give the Meridian Zenith Diſtance of the Sun's Centre more correctly than it could be deduced from the Zenith Diſtance of one Limb only with the Sun's Semidiameter applied to it.

The general Rule for reading off the obſerved Zenith Diſtance is this; ſet the Index of the Micrometer to (0), and turn the Screw that Way, which will cauſe the Figures of the divided Circle to paſs by the Index in their proper Order, till the firſt Coincidence happens between a Stroke on the Vernier and one of the Diviſions. From the Zenith Diſtance at which the Teleſcope now ſtands (ſhewn by the Diviſions and Vernier) ſubtract the Seconds ſhewn by the Micrometer, and you will have the Zenith Diſtance required. It may not be improper here to remark, that the Screw of the Micrometer ought, by Rights, to be turned the ſame Way in reading off, which was done in the Obſervation; elſe, if there be any Shake or Play in the Screw upon turning it different Ways (as is generally the Caſe) an Error will be incurred. It may perhaps be conducive to greater Certainty to repeat the Reading two or three Times, by turning the Screw of the Micrometer a little back each Time, and then ſcrewing it forwards again, to produce a freſh Coincidence of the Vernier with the Diviſions, as the Mean of the Numbers of the Micrometer ſo found will, in all Probability, be more exact than a ſingle Reading. In the Day Time it will be uſeful for the better reading off the Obſervations to throw Light by Reflection from white Paper upon the Diviſions and Vernier, but in the Night they muſt be illuminated by a Candle or Lamp.

The Obſervation of Zenith Diſtances of the heavenly Bodies at a Diſtance from the Meridian is performed much in the ſame Manner as of thoſe on the Meridian, except that the Teleſcope is generally ſet to ſome even Diviſion, and the Times by the Clock of the Tranſits of the Star or both Limbs of the Sun acroſs the horizontal Wire paſſing through the Centre of the Teleſcope are obſerved; and alſo, if it is intended to find the Time by equal Altitudes on each Side of the Meridian, acroſs ſuch other Wires as may be placed in the Teleſcope parallel thereto for this Purpoſe.

The Mean of the Times by the Clock of the Tranſit of a Star, when obſerved at the ſame Wire, and with the Teleſcope fixed to the ſame Altitude on both Sides of the Meridian, gives the Time by the Clock of the Star paſſing the Meridian; whence either the Apparent or Mean Time is eaſily computed, and conſequently the Error of the Clock found: But the Mean of the Times of the Tranſits of the ſame Limb of the Sun acroſs the ſame Wire on different Sides of the Meridian muſt be firſt corrected by the Equation, commonly called by the Title of that of correſponding Altitudes (a Table of which is to be found at the End of theſe Remarks) in order to have the Time by the Clock of the ☉'s Centre paſſing the Meridian, which is the Apparent Noon; whence the Error of the Clock is alſo determined. The Method of deducing the Time from correſponding Altitudes is ſo much the more exact, as the Accuracy of it is not affected by any Uncertainties about Refraction or the Latitude of the Place, or even the Declination of the heavenly Bodies; moreover it is rendered ſtill more exact, if the Times of the Star or Sun's Limbs, paſſing the Wires of the Teleſcope fixed ſucceſſively at ſeveral Altitudes, be obſerved; the Number of Reſults for the Time of the Paſſage acroſs the Meridian being hereby multiplied, it may be preſumed, that the Mean of all the Reſults will come much nearer the Truth than a ſingle One.

The Obſervations made on the Weſt Side of the Meridian follow one another in an inverted Order, with reſpect to their correſponding ones taken on the Eaſt Side. Thus the Time of the Tranſit of the Sun's upper Limb acroſs the lower Wire is the firſt Obſervation in the Morning, but is the laſt in the Afternoon; and the Tranſit of the Sun's lower Limb acroſs the upper Wire is the laſt Obſervation in the Morning, but the firſt in the Afternoon; Therefore it will be moſt convenient in Practice to ſet down the Obſervations made on the Weſt Side of the Meridian in an inverted Order to that in which they are made under thoſe made on the Eaſt Side of the Meridian, and thus they will immediately correſpond to thoſe which ſtand over them, and the Mean of each Pair of correſponding Ones will be readier ſeen. The Obſerver will not forget that the Teleſcope inverts Objects, ſo that the Limb which appears the upper Limb is really the lower Limb, and is to be called ſo, and the Limb which appears the lower One is really the upper One, and is to be called ſo. Though the Method of finding the Time from equal Altitudes of the ☉, or ✱'s obſerved on both Sides of the Meridian, be much more accurate and ſatisfactory than that of inferring it by Computation from ſingle Altitudes, yet, if by any Accident the correſponding Obſervations cannot be taken, the Time may be deduced nearly, in Caſe of Neceſſity, from the latter Method, the Latitude of the Place being ſuppoſed known.

The Eaſtern and Weſtern Azimuths of any cœleſtial Body being equal when it has equal Altitudes on contrary Sides of the Meridian, it will be eaſy to find by the Azimuth Circle belonging to the Quadrant, about what Azimuth to place the Quadrant on the Weſt Side of the Meridian, in order to make the correſponding Obſervations to thoſe taken before on the Eaſt Side; provided the Point (o) on the Azimuth Circle is ſet to agree truly or very nearly with the Meridian, or at leaſt the Error of its Poſition with reſpect to the Meridian is known.

The Azimuth Circle may alſo be of Uſe for placing the Quadrant in the Meridian for taking Meridian Altitudes, though this will be better done by the Means of a Meridian Mark. Such a Mark may be readily placed, as well as the Poſition of the Azimuth Circle determined, as follows: Having found from repeated equal Altitudes of the Sun or fixed Stars how much the Clock differs from mean Time, and alſo the Rate of its gaining or loſing in a Day, make a Computation at what Hour, Minute, and Second, by the Clock, the Sun or Star ſhould paſs the Meridian on any Day, and having directed the Teleſcope of the Quadrant to the Object a little before the expected Time of its paſſing the Meridian, ſo that the vertical Wire of the Teleſcope may paſs over the Star or ⊙'s Centre, turn the Quadrant gradually about upon its Axis, by Means of the proper Screw, which in the Time of Obſervation is to be faſtened by a Clamp to the Azimuth Circle, ſo as to cauſe the vertical Wire to keep equal Pace with the Sun or Star's diurnal Motion, and always to paſs over its Centre, till the Clock points out the computed Time at which the Object ſhould paſs the Meridian; at that Inſtant the Plane of the Quadrant is placed truly in the Meridian; then bring the lower End of the Teleſcope up towards the horizontal Line, and fix up ſome Mark at a Diſtance which may be covered or biſected by the vertical Wire of the Teleſcope, and it will be placed truly in the Direction in the Meridian; ſo that whenever you want to ſet the Plane of the Quadrant in the Meridian for obſerving Meridian Altitudes, you have nothing to do but to adjuſt the Quadrant in the uſual Manner, and turn it about till the vertical Wire in the Teleſcope biſects the Mark, and the Quadrant will be truly adjuſted to the Meridian. Inſtead of following the ⊙'s Centre, it will be more convenient and exact to follow his Eaſtern or Weſtern Limb with the vertical Wire of the Teleſcope till the computed Time happens by the Clock of the Limb paſſing the Meridian; the Weſtern Limb paſſes ſooner, and the Eaſtern Limb paſſes the Meridian later than the ⊙'s Centre, by the Time that the ⊙'s Semidiameter takes to paſs the Meridian, which maybe found in the Nautical Almanac; therefore this Quantity being ſubtracted from the computed Time by the Clock of the Sun's Centre paſſing the Meridian, gives the Time of the Weſtern Limb paſſing the Meridian, or added to the Time of ⊙'s Centre paſſing the Meridian, gives the Time of the Eaſtern Limb paſſing the Meridian.

The Quadrant being once ſet truly in the Meridian, it will be eaſy to adjuſt the Point (o) of the Azimuth Circle to the Meridian, or to note the Error of its Poſition.

But it ſhould be carefully attended to, that the Quadrant cannot be adjuſted truly to the Meridian, for future Obſervations, either by the Meridian Mark or Azimuth Circle, unleſs the Pedeſtal of the Inſtrument has a fixed Poſition in the Obſervatory, which may be beſt effected by having the Pillar or Stand on which you place the Braſs Pedeſtal immoveable, and ſinking little Holes on the horizontal Top of it to receive the 4 Screws of the Pedeſtal, whereby it will be eaſy to replace the Pedeſtal in the ſame Manner again after any Removal.

If the Mark be only 1000 Feet diſtant, the Pedeſtal ſhould be adjuſted always to the ſame Poſition again with reſpect to the Meridian within $\frac{1}{10}$ of an Inch, and nearer if the Mark be leſs diſtant. A Poſt fixed firmly in the Ground, and ſet truly perpendicular by means of a Plumbline or Carpenter's Level, will be very proper for a Meridian Mark, and if ſeen againſt the Ground ſhould be painted white, but if ſeen againſt the Sky ſhould be painted black.

Hitherto I have ſuppoſed the Quadrant to be correct with reſpect to thoſe Adjuſtments, which when once made, either by the Inſtrument Maker or Obſerver, are uſually invariable, except the Inſtrument meets with any violent Concuſſion in Carriage or otherwiſe. As it is the Buſineſs of the Obſerver to verify theſe Particulars himſelf before he begins to make any Obſervations, I ſhall now offer to him a few Directions, as I propoſed, for that Purpoſe.

In the Firſt Place the Object-Glaſs and Eye-Glaſs of the Teleſcope muſt be ſet to a due Diſtance from one another, and from the croſs Wires, that both the cœleſtial Objects and the Wires may be ſeen diſtinct by the Eye of the Obſerver, and at the ſame Time there may appear no Parallax or Motion of the Object, with relation to the Wires, when the Eye is moved ſide-ways out of the Axis of the Tube. For this Purpoſe take off the Cover of the Tube near the Eye, and direct the Teleſcope to ſome fixed Star or Planet, and draw the Eye-Glaſs a little further out, and puſh it gently a little further into the Tube, alternately, till by repeated Trials you have placed it in that Poſition in which it ſhews the cœleſtial Object with the moſt Diſtinctneſs;

and note whether at the ſame Time you ſee the croſs Wires near the Place of their Interſection with more Diſtinctneſs than in any other Poſition of the Eye-Glaſs, and alſo whether the Object appears immoveable, with reſpect to the Wires, upon moving your Eye ſideways; if both theſe Circumſtances concur (as they will do at the ſame Time, provided the Teleſcope with its Wires had been properly adjuſted before to Diſtinctneſs for any Eye) your Teleſcope is now rightly adjuſted for Diſtinctneſs to your Eye.

But if the Wires do not appear perfectly diſtinct to your Eye, or the Object appears to move, with reſpect to the Wires, when the Eye is moved ſide-ways, it follows, that the Diſtance, either of the Object-Glaſs or croſs Wires in the Tube, or both, muſt be altered; it will be more eaſy and convenient to move the Wires, provided they are ſo placed as to admit of it: In this Caſe, carry them further from the Eye, and bring them nearer to it, alternately, till you have placed them at that Diſtance at which you ſee them with the moſt Diſtinctneſs, and at the ſame Time there remains no Parallax of the cœleſtial Object upon the Wires when the Eye is moved ſideways.

But if the Wires are incapable of being removed, place the Eye-Glaſs at that Diſtance with which it will ſhew them moſt diſtinct, and then alter the Diſtance of the Object-Glaſs in the Tube, one Way or the other, till you can ſee the cœleſtial Object the moſt diſtinct, and at the ſame Time there ſhall be no Parallax of the Object upon the Wires; and the Teleſcope is fitted to Diſtinctneſs for your Eye; and, it is evident, will require no Adjuſtment of this Kind another Time, except in Proceſs of Time the Form of the Eye ſhould ſuffer any Alteration: In this Caſe, or if any other Perſon more ſhort-ſighted or long-ſighted in any conſiderable Degree, ſhould have Occaſion to uſe the Quadrant, all that is neceſſary to be done is to alter the Place of the Eye-Glaſs in its Tube till the cœleſtial Objects appear more diſtinct.

In the next Place, the Wire which, in taking Altitudes, is brought to the Star or Sun's Limb, ſhould lie truly horizontal,

rizontal, when the Plane of the Quadrant has been adjuſted perpendicular to the Horizon by the Method related above, Direct the Teleſcope to any ſmall, well-defined Object or Mark upon Land, or if none ſuch can be found, fix One up at a convenient Diſtance, and having biſected it carefully by the Wire that ought to be horizontal, turn the whole Quadrant a little about in Azimuth, and if, during this Motion, the Mark is continually biſected by the different Parts of the Wire, as they are ſucceſſively applied to it, the Wire is truly horizontal; but if the Wire ceaſes to biſect, or leaves the Mark, preſs the Two Screws, One of which is on the upper and the other on the under Side of the Teleſcope, near the Eye, and which enter into the Plate in which the croſs Wires are fixed, between your Finger and Thumb, and turn them ſideways, but in contrary Directions, till the horizontal Wire, upon Re-examination, on moving the Quadrant, always agrees with the Mark. A ſmall white Circle placed upon a black Ground, or a black Circle placed upon a white Ground, will be a proper Mark for this Purpoſe. One of the Firſt Sort will be formed by a Hole cut in a Board painted black, and ſeen againſt the Sky. Otherwiſe the Wire may be adjuſted by a Star, in or near the Equator paſſing the Meridian, which ought to continue biſected by it all the while it is paſſing the Field of the Teleſcope. Or, without waiting for the Star's running over the whole Length of the Wire, turn the Quadrant a little about, at or very near the Time of the Star's paſſing the Meridian; and note whether the Wire continues in the Parts near the Centre of the Teleſcope to biſect the Star.

The laſt Adjuſtment which it is incumbent on the Obſerver to verify, is that of ſetting the Line of Collimation or Line of Sight, which joins the Centre of Refractions in the Object-Glaſs, and the Interſection of the Wires of the Teleſcope, parallel to the Radius paſſing through the Firſt Stroke of the Vernier.

I ſhall mention Two Methods of doing this by means of terreſtrial Objects, and One by Obſervations of the Stars.

Firſt Method. Set the Teleſcope to the horizontal Radius of the Quadrant, ſo that the Firſt Stroke of the inner Vernier may agree with the Diviſion or Zenith Diſtance marked 90° on the inner Arch of the Quadrant, and that the Firſt Stroke of the other Vernier may agree with the Diviſion marked 96 on the outer Arch.

Make Two Marks on a Board (as Two ſmall white Circles the Board being painted black, or Two black Circles the Board being painted white) at a Diſtance exactly equal to the Difference of the Altitudes of the Teleſcope, ariſing from inverting the Quadrant.

Place the Board at a Diſtance, and ſet the Line joining the Two Marks truly perpendicular to the Horizon by means of a Plumb-line, and at ſuch a Height that the Interſection of the croſs Wires of the Teleſcope may appear exactly coincident with the Centre of the upper Circle, the Plumb-line of the Quadrant at the ſame Time being made to biſect both the Points marked with Darts.

Then invert the Quadrant, and hanging on the Plumb-line again, from an Apparatus contrived to be fitted occaſionally upon the Arch, cauſe it to paſs over and biſect both Points, by turning the *Adjuſting Screw*, and if the Interſection of the croſs Wires covers the Centre of the lower Mark, the Line of Collimation of the Quadrant is correct. But, if otherwiſe, ſet the Index of the Micrometer to (0), and turn its Screw one Way or the other, till the Interſection of the Wires covers the Centre of the lower Mark, and the Angle moved over by the Teleſcope, which is indicated by the Number of Seconds run over by the Index of the Micrometer, is equal to double the Error of the Line of Collimation. If the Error be but ſmall, it may be as convenient to allow for it in the Obſervations; but if it be large, correct it as follows: Turn the Micrometer Screw back, ſo as to point out Half the double Error which it ſhewed, and eaſe one of the ſmall Screws, and ſcrew up the oppoſite One of thoſe Two upon the Teleſcope which govern the croſs Wires, till the Interſection of the Wires covers the Centre of the lower Mark; and the Line of Collimation ſhould now be correct. For greater Certainty repeat the Operation thus; ſet the Teleſcope again to the 90th Degree, as before, and examine anew whether the Plumb-line continues to biſect the Points, and if it does not, make it to do ſo by turning the *Adjuſting Screw*, and alter the Height of the Board with the Marks, till the Centre of the lower Mark is covered by the Interſection of the croſs Wires; then turn back the Quadrant into its firſt Poſition, and cauſing the Plumb-line again to biſect the Points, by turning the *Adjuſting Screw*, if neceſſary, examine whether the Interſection of the croſs Wires covers the Centre of the upper Mark. If it does, the Line of Collimation is correct; but if it does not, it may be corrected, or the Quantity of the Error found, in the Manner deſcribed above.

This Examination muſt be repeated in the ſame Manner, by inverting and replacing the Quadrant, till the Line of Collimation appears correct, or till the exact Quantity of the Error is found. If it ſhould be thought more expedient to allow for the Error of the Line of Collimation, take the following Rule for the Manner of applying it: If, after the Inverſion of the Quadrant, the lower Mark appears through the Teleſcope lower than the Interſection of the croſs Wires, or if, after replacing the Quadrant in its firſt Poſition, the upper Mark appears higher than the Interſection of the Wires, the Error of the Line of Collimation is of that kind as to give the Zenith Diſtances greater than the Truth, and conſequently the Error muſt be ſubtracted from the obſerved Zenith Diſtances; but if, in the Firſt Caſe, the lower Mark appears through the Teleſcope higher, or in the Second Caſe lower than the Interſection of the Wires, the Error of the Line of Collimation gives the Zenith Diſtances too little, and conſequently the Error muſt be added to the obſerved Zenith Diſtances.

Otherwiſe the Error of the Line of Collimation may be more readily found as follows, without taking the Trouble of placing the Marks at ſuch a Height as to agree with the

Interſection of the croſs Wires, while the Teleſcope is always ſet to the Zenith Diſtance of 90 Degrees. Meaſure the Zenith Diſtance of the upper Mark by the Diviſions, Vernier, and Micrometer; then, inverting the Quadrant, take the Zenith Diſtance of the lower mark; add the Two Zenith Diſtances together, and Half the Difference of the Sum and 180 Degrees is the Error of the Line of Collimation, which is to be ſubſtracted from or added to all Obſervations, according as the Sum of the Two Zenith Diſances was here found greater or leſs than 180 Degrees. It may be added, that Half the Difference of the Two Zenith Diſtances found in the Two Poſitions of the Quadrant is the apparent Altitude of the upper Mark.

The other Method of examining the Line of Collimation by terreſtrial Objects is this: Set the Teleſcope to the 90th Degree and 96 Diviſion, and having cauſed the Plumb-line to biſect the Points, ſet up ſome Mark at a Diſtance, ſo that the Interſection of the croſs Wires may biſect it; then remove the Quadrant and Mark into each others Place, ſo that the Centre of the Teleſcope and the Centre of the Mark may be mutually and preciſely interchanged; and the Plumb-line being re-adjuſted to the Points, note whether the Interſection of the Wires covers the Centre of the Mark; if it does not, ſet the Index of the Micrometer to (0), and turn the Screw till it does; you will thus have read off the apparent Zenith Diſtance of the Mark; from which ſubtract the Number of Seconds of an Arch of a great Circle of the Earth anſwering to the Diſtance of the Quadrant from the Mark (at the Rate of 102 Feet for each Second) the Difference of the Remainder, and 90° is double the Error of the Line of Collimation; hence the Line of Collimation may be rendered correct (if required) by a Manner much like that deſcribed in the Uſe of the former Method.

The Error of the Line of Collimation will be of that Kind as to ſhew the Zenith Diſtances too great or too little, according as the Zenith Diſtance of the Mark obſerved from the Second Station leſſened by the Diſtance turned into

Seconds of an Arch of a great Circle is greater or leſs than 90°.

The third Method of verifying the Line of Collimation is by taking Zenith Diſtances of fixed Stars with the Face of the Inſtrument turned Eaſt and Weſt alternately; for which Purpoſe, the Arch is continued and divided for a few Degrees beyond a Quadrant; and in one Poſition of the Quadrant the Zenith Diſtance of ſome Star is obſerved with the Teleſcope contained within the Quadrantal Arch, and in the other Poſition of the Quadrant the Zenith Diſtance of the ſame Star is taken with the Teleſcope falling upon the Arch of Exceſs; if both the Zenith Diſtances agree together, the Line of Collimation is correct; but if they differ, Half the Difference is the Error of the Line of Collimation, which added to the leaſt Zenith Diſtance of the two, or ſubtracted from the greateſt, gives the correct Zenith Diſtance.

And, according as the Zenith Diſtance, when the Teleſcope falls within the Quadrantal Arch, is greater or leſs than the other, the Error of the Line of Collimation is to be ſubtracted from or added to all Zenith Diſtances taken in this Poſition of the Quadrant, and applied in a contrary Manner to Obſervations made with the Teleſcope falling without the Quadrant. It is hardly neceſſary to remark, that theſe Obſervations made with the Quadrant turned contrary Ways, muſt fall within the Compaſs of a few Days, elſe there will be an Allowance to be made on account of the Variation of the Star's Declination.

It may not be an improper Caution to give the Obſerver, that the Object-Glaſs of the Teleſcope muſt not be taken out or removed in the Tube, on any Account, after the Line of Collimation has been corrected, or the Error of it determined, becauſe ſuch Removal would diſturb the ſame. Therefore the Object-Glaſs muſt be cleaned, when neceſſary, without Violence, on the Outſide only; the inner Surface, which is ſecured from the Air, being not commonly ſubject to acquire much Soil, except in a long Space of Time.

There are ſome particular Circumſtances relative to the Obſervations of Stars near the Zenith which I ſhall take the Opportunity of mentioning in this Place.

I. To eaſe the Obſerver from the Trouble of looking up ſo high, there are metallic Speculums provided, to be placed occaſionally in the Tube of the Teleſcope between the Eye-glaſs and the Eye, making an Angle of 45° with the Axis of the Tube, which will conſequently reflect the Field of the Teleſcope, and the cœleſtial Objects, together with the Wires, directly to the Eye of the Obſerver, looking horizontally againſt the Speculum and the Side of the Tube.

II. As the Teleſcope muſt always be ſet to its Altitude before the Plumb-line is adjuſted, leſt the Alteration of its Preſſure upon the Feet of the Pedeſtal, ariſing from moving it, ſhould diſturb the Plumb-line; and as the Teleſcope, when placed near the Zenith, will interfere with the Plumb-line, if ſuſpended in its uſual Poſition; therefore an Apparatus is provided to be faſtened upon the horizontal Side of the Quadrant, containing a Notch, from which the Plumb-line is to be hung in ſuch Caſes, and it is to be carried to the Right or Left, partly by means of a Screw which governs the Notch, and partly by the *Adjuſting Screw*, till it is brought to hang directly over and biſect two Points marked with Darts, one of which is on the Side of the Quadrant immediately under the Notch, and the other on the Limb of the Quadrant, and are ſet off exactly equidiſtant from the Centre and the Extremity of the Radius paſſing through (0) as the other two Points marked with Darts were, but on the contrary Side.

III. In reading off the Zenith Diſtance, when obſerved on the Arch of Exceſs, inſtead of the Number of the Vernier, which is made to coincide with a Diviſion, read its Complement to 32, and inſtead of ſubtracting the Seconds ſhewn by the Micrometer, add them to the Zenith Diſtance thus given by the Diviſions and Vernier.

There are Two remaining Adjuſtments of the Quadrant which I ſhall only mention, without laying any great Streſs upon them, becauſe the Effect of a ſmall Error in them is of leſs Conſequence, and that they are moreover generally rendered correct by the Inſtrument Maker in the Conſtruction. The firſt is the ſetting the Line of Collimation parallel to the Plane of the Quadrant; the other is the placing the Plane of the Quadrant parallel to the Axis of the Pillar. The Obſerver may, if he pleaſes, adjuſt theſe Particulars alſo, provided there is any Liberty left for it in the Conſtruction of the Inſtrument.

I have now finiſhed the Deſcription of the Uſe of the Aſtronomical Quadrant of Mr. *Bird*'s Conſtruction.—Inſtruments made by other Artiſts may differ from his in ſeveral Particulars, and among theſe in the Adjuſtments; but whoever well underſtands the foregoing Account will, I think, hardly be at a Loſs to know how to adjuſt and uſe any of theſe Quadrants, as the Points to be adjuſted are the ſame, and therefore the Difference of the Contrivances deſigned for the ſame Purpoſe will appear upon the Face of the Inſtrument.

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Here follows a TABLE ſerving for the Reduction of the Diviſions and Vernier of the exterior Arch of Mr. BIRD's Quadrants of One Foot Radius, into Degrees, Minutes, and Seconds.

Grand Diviſions.												Subdiviſions.			Vernier.		
	°	′	″		°	′	″		°	′	″		M.	S.		M.	S.
1	0	56	15	33	30	56	15	65	60	56	15	1	14.	3,7	1	0.	26,4
2	1	52	30	34	31	52	30	66	61	52	30	2	28.	7,5	2	0	52,8
3	2	48	45	35	32	48	45	67	62	48	45	3	42.	11,2	3	1	19,1
4	3	45	0	36	33	45	0	68	63	45	0				4	1	45,5
5	4	41	15	37	34	41	15	69	64	41	15				5	2	11,8
6	5	37	30	38	35	37	30	70	65	37	30				6	2.	38,2
7	6	33	45	39	36	33	45	71	66	33	45				7	3	4,6
8	7	30	0	40	37	30	0	72	67	30	0				8	3	30,9
9	8	26	15	41	38	26	15	73	68	26	15				9	3	57,3
10	9	22	30	42	39	22	30	74	69	22	30				10	4.	23,7
11	10	18	45	43	40	18	45	75	70	18	45				11	4	50,0
12	11	15	0	44	41	15	0	76	71	15	0				12	5	16,4
13	12	11	15	45	42	11	15	77	72	11	15				13	5.	42,8
14	13	7	30	46	43	7	30	78	73	7	30				14	6	9,1
15	14	3	45	47	44	3	45	79	74	3	45				15	6	35,5
16	15	0	0	48	45	0	0	80	75	0	0				16	7.	1,9
17	15	56	15	49	45	56	15	81	75	56	15				17	7	28,2
18	16	52	30	50	46	52	30	82	76	52	30				18	7	54,6
19	17	48	45	51	47	48	45	83	77	48	45				19	8	21,0
20	18	45	0	52	48	45	0	84	78	45	0				20	8	47,3
21	19	41	15	53	49	41	15	85	79	41	15				21	9	13,7
22	20	37	30	54	50	37	30	86	80	37	30				22	9	40,1
23	21	33	45	55	51	33	45	87	81	33	45				23	10	6,4
24	22	30	0	56	52	30	0	88	82	30	0				24	10	32,8
25	23	26	15	57	53	26	15	89	83	26	15				25	10	59,2
26	24	22	30	58	54	22	30	90	84	22	30				26	11.	25,5
27	25	18	45	59	55	18	45	91	85	18	45				27	11	51,9
28	26	15	0	60	56	15	0	92	86	15	0				28	12	18,3
29	27	11	15	61	57	11	15	93	87	11	15				29	12.	44,6
30	28	7	30	62	58	7	30	94	88	7	30				30	13.	11,0
31	29	3	45	63	59	3	45	95	89	3	45				31	13	37,4
32	30	0	0	64	60	0	0	96	90	0	0						

But ſhould the Obſerver be unprovided with the Aſtronomical Quadrant, he may find the Time nearly by equal Altitudes of the Sun, taken with a *Hadley's* Quadrant, from the Horizon of the Sea, if he is near it; but much better by taking the double Altitude by Reflection from a Baſon of Water, Quickſilver, Oil, or Treacle. In the Uſe of this latter Method there are Three Obſervations to be taken with the ſame Setting of the Quadrant; namely, the Time when the Sun's upper Limb, as reflected by the Quadrant, touches the Sun's lower Limb, as it appears in the Baſon, the Time of the Two Suns reflected from the Quadrant and Baſon appearing centrally conjoined together; and the Time of the lower Limb, as reflected from the Quadrant, touching the upper Limb, as it appears in the Baſon. Theſe are the Times at which the double Altitudes of the Sun's upper Limb, Centre, and lower Limb are equal to the Degrees and Minutes marked by the Quadrant; and this is the Order in which the Three Obſervations follow one another in a Morning, but in an Afternoon the Order is reverſed. The Mean of the Times of the equal Altitudes of the ſame Limb gives the Time of Noon as uſual; the ſame is given by the equal Altitudes of the Centre; thus, One Setting of the Quadrant gives Three Reſults for the Time of Noon, the Mean of which may be taken, and muſt be corrected by the Equation of correſponding Altitudes in the common Manner. The Obſervation of the Contacts of the Two Limbs is rather more certain than that of the Conjunction of the Centres. A dark Glaſs muſt be held near the Eye to darken both Images of the Sun together.

It is evident, that the Latitude of the Place may alſo be found by taking the double Altitude of the Sun's upper Limb, lower Limb, or Centre, at the Time of his paſſing the Meridian. Half the double Altitude thus found is to be corrected by Refraction as uſual.

By way of a laſt Reſource, the Time of Noon may be found by a Meridian Line drawn by the Help of a Gnomon, and the Latitude may alſo be deduced from the ſame. Make a ſmall Hole in a Plate of Metal, placed ſo that the Sun's Rays may fall perpendicularly upon it at Noon about the Time of the Equinoxes, and at as great a Height as poſſible above an even Floor that is well levelled. Hang a Plumb-line through the Centre of the Hole, and mark the Point on the Floor which lies directly under the Point of the Plummet (which ſhould be turned truly conical, at leaſt on the lower Part) for the Centre of the Gnomon, from which deſcribe ſeveral concentric Arches upon the Floor. On the Day of the Solſtice, or not many Days from it, the Sun's Light being admitted through the Hole in the Plate, mark the Place of the Centre of his Image when it paſſes each of the concentric Arches in the Morning, and repeat the ſame Operation in the Afternoon. Biſect the Portion of any Arch intercepted between the Two correſpondent Stations of the Sun's Centre in the Morning and Afternoon, and the Line drawn through the Point of Biſection, and the Centre of the Gnomon is the Meridian Line. In like Manner the Meridian Line will be found by Means of the Points marked upon the other concentric Arches, which ought all to agree together; but if there is any Difference, a Line may be drawn whoſe Poſition is taken at a Medium between them all for the true Meridian Line. Whenever the Sun's Centre paſſes this Line at any Time of the Year it is Noon. To find the Latitude of the Place, meaſure with a good Ruler or Scale of equal Parts the exact Diſtance between the Centre of the Hole in the Plate and the Centre of the Gnomon, which is called the Height of the Gnomon, and when the Sun paſſes the Meridian upon any Day, mark the Centre of his Image upon the Meridian Line, and meaſure its Diſtance from the Centre of the Gnomon, and ſay, as this Diſtance is to the Height of the Gnomon, ſo is the Radius 100000 to a natural Tangent, which being ſought for in the Tables, and a Proportion being made, if neceſſary, will give the apparent Altitude of the Sun's Centre, whence the Latitude may be found according to the uſual Methods. If the Latitude be thus found on ſeveral other Days, and at other Times of the Year, the Mean of all being taken will come ſtill nearer to the Truth.

I now return to add ſome further Remarks concerning the Tranſit of Venus over the Sun's Diſk. It may be difficult to catch the Inſtant of the Firſt external Contact; but as it may be expected (from Calculation) that the Firſt Impreſſion of Venus upon the Sun's Limb will fall about 37 Degrees to the Eaſt of that Point of the Sun's Circumference which is neareſt the North Pole of the World, the Obſervers will do well always to keep this Part of the Sun's Limb as near as they can eſtimate it, not far from the Middle of the Field of their Teleſcope, and to regard it principally, yet ſo as not to neglect the Parts adjacent. There was a Circumſtance taken Notice of by the Rev. Mr. *Hirſt*, F. R. S. who obſerved the laſt Tranſit of Venus at *Madras*, which if we could depend upon its taking Place again at the next Tranſit, would prove a good Help towards catching the Point of Immerſion and the true Inſtant of it. This was a Kind of Penumbra or duſky Shade, which preceded the Firſt external Contact 2 or 3 Seconds of Time, and was ſo remarkable that Mr. *Hirſt* was thereby aſſured that the Contact was approaching, which happened accordingly. If the like Phænomenon ſhould occur to any Perſon who attends the enſuing Tranſit, this Hint will prepare him to make a proper Uſe of it; yet I think it neceſſary to caution him not to keep his Eye intirely fixed on the Part of the Sun's Limb where ſuch an Appearance may happen, leſt his Imagination may deceive him, and thereby take off his Attention from the other Parts of the Sun's Circumference, and conſequently from the Point where the external Contact may really happen. Several Aſtronomers at the laſt Tranſit obſerved a luminous Creſcent at the Times of the Ingreſs and Egreſs, which enlightened that Part of Venus's Circumference which was off the Sun, ſo that the Whole of her Circumference was viſible: This was alſo obſerved by One Perſon at the Middle of the Tranſit. Mr. *Dunn*, with a *Newtonian* reflecting Teleſcope of 6 Feet, magnifying 220 Times, obſerved a very narrow wateriſh Penumbra round Venus, while ſhe was wholly on the Sun, which ſomewhat diſturbed the Diſtinctneſs of the Termination of her Circumference: Something of the ſame Kind was taken Notice of by ſome other Obſervers. If theſe Phænomena ſhould be fully confirmed by the Obſervations of the next Tranſit, they will probably be allowed to be the Effects of an Atmoſphere about that Planet. Four able Aſtronomers at *Upſal*, furniſhed with good Teleſcopes, ſaw Venus's external Limb about the Time of the Firſt internal Contact, to be united to the Sun's Limb by a black Protuberance or Ligament, which was not broke by the Entrance of the Thread of Light till ſeveral Seconds after that the regular Circumference of Venus ſeemed to coincide with the Sun's: In theſe Obſervations the Sun was only 3½ Degrees high; and the Indiſtinctneſs of Viſion occaſioned by the Vapours near the Horizon might have been thought to be Cauſe of this Appearance; but that the like was obſerved (though leſs plain and remarkable) at the Second internal Contact, when the Sun's Altitude was conſiderable.

Something of the ſame Kind was alſo ſeen by Mr. *Rumouſki* at *Selenginſk*, in an unfavourable State of Air, at the Second internal Contact; and by Mr. *Hirſt* at *Madraſs* at both internal Contacts. Mr. *Thorbern Bergman*, who was One of the Obſervers at *Upſal*, relates that Venus ſeemed to cohere to the Sun by a Ligament at the Second external Contact alſo. Such Effects might be produced either by an Atmoſphere about Venus, Imperfections of a Teleſcope, or a bad State of Air; but from the Accounts publiſhed it does not appear to me that there was any Fault in the Teleſcopes.

Dr. *Halley* had ſuppoſed that the internal Contacts would be in a Manner inſtantaneous, or at leaſt that they might be obſerved without a greater Error than One Second of Time; but in fact this Suppoſition was not verified by the Obſervations of the laſt Tranſit. The Thread of Light between the Limbs of Venus and the Sun was not broke off in an Inſtant, at the Second internal Contact, as he had ſuppoſed it would, but gradually, with an Uncertainty of ſome Seconds; and the Obſervations made by experienced Obſervers in the ſame Place, or in Places not far diſtant, and reduced to the ſame Meridian, differed accordingly from one another more than was expected. Part of theſe Differences might ariſe from the Difference of Judgment in eſtimating the Contact, ſome noting the Time when the Thread of Light became inviſible, and others the Time when the Circumference of Venus ſeemed to coincide with the Sun's. It is therefore to be wiſhed, that thoſe who obſerve the next Tranſit will in the Account of their Obſervations mention particularly in what Manner they judged of the internal Contacts.

After the Obſervation of the Contacts, that of the neareſt Diſtance of the Centres of the Sun and Venus being the next in Importance, it is recommended to thoſe who ſhall be ſituated in Places where the Middle of the Tranſit is viſible, and be furniſhed with the proper Inſtruments, to attend to this Point alſo.

The common Micrometer having a moveable Wire parallel to a fixed one, and a Third perpendicular to both, may be made uſe of in this Occaſion; but the Inſtrument, which is by far the moſt convenient and exact for this Purpoſe, is the divided Object-Glaſs Micrometer, commonly called *Dollond*'s Micrometer, fitted to the Object-end either of a reflecting Teleſcope, or an Achromatic refracting Teleſcope of 3½ Feet, with a treble Object-Glaſs. The Method of uſing this Micrometer is very ſimple and eaſy; it may however be proper to give a brief Deſcription of it. The Two Semicircles into which the Object-Glaſs is divided are ſeparated from each other by turning an Handle, and the Diſtance of their Centres is meaſured by a Scale of equal Parts divided into Inches and 20ths of an Inch, with the Addition of a Vernier, which ſubdivides the 20ths of an Inch of the Scale into 25 Parts, or the 500th Parts of an Inch. The Rays of Light paſſing through each Semicircular Glaſs will exhibit a particular

Image of an Object to an Eye looking through the Teleſcope. When the Semicircles are brought together, ſo that their Centres coincide, and they form as it were but One Glaſs, the Two Images being united together, only One Image of an Object will be ſeen; but in proportion as the Glaſſes are ſeparated from each other by turning a Handle, the Two Images will be ſeen to ſeparate alſo. To meaſure the angular Diſtance of Two Objects (not exceeding the Extent of the Micrometer) bring the Image of One Object formed by One of the Semicircles to coincide with the Image of the other Object formed by the other Semicircle, which is to be done, partly by turning the Handle which ſeparates the Two Glaſſes, and partly by turning the other Handle which will carry the common Diameter dividing the Two Glaſſes into the Plane paſſing through the Two Objects; and read off the Numbers from the Scale and Vernier, and you will have the apparent Diſtance by the Scale, which is to be turned into Minutes and Seconds by Means of a Table to be formed for that Purpoſe. To meaſure the apparent Diameter of a Planet the Two Images muſt be ſeparated till their Circumferences touch one another externally.

The Firſt Thing to be done, in order to fit the Inſtrument for Obſervation, is to adjuſt the Teleſcope, with the Micrometer applied to it, to the moſt perfect Viſion of the Object to be obſerved. Cover One of the Semicircles, ſo as to intercept One of the Images of the Object, and alter the Focus of the Teleſcope both Ways ſeveral Times, till you have adjuſted it, to ſhew the other Image formed by the Glaſs that is uncovered with the greateſt Diſtinctneſs. The Sun's Limb, or Spots, or the opaque Body of Venus during the Tranſit, are very good Objects for this Purpoſe.

If there is a Scale with a Vernier placed on the Side of the Teleſcope (as uſual) repeat the Adjuſtment of the Teleſcope ſeveral Times, and note the Number indicated by the Scale and Vernier each Time, the Mean of all the Numbers is that according to which the Teleſcope muſt be adjuſted, or the Adjuſtment reſtored at another Time, if it ſhould have ſuffered any Alteration. Great Care is neceſſary to be uſed in this Point, as a very ſmall Error therein will occaſion a ſenſible Alteration in the Angle as meaſured by the Micrometer Scale.

The next Thing to be done is to find the Error of the Adjuſtment of the Micrometer Scale. Both Micrometer Glaſſes being now expoſed to the Object, turn the Handle which moves the Glaſſes with reſpect to each other, till both Images of the Object are conjoined in One, and the Numbers ſhewn by the Scale and Vernier is the Error of the Adjuſtment. This Object may be any of the celeſtial Bodies, or even a diſtant well-defined Land Object, and, the Experiment being repeated ſeveral Times, the Mean of all ſhould be taken for the true Quantity of Error, and if (o) on the Vernier falls before or to the Right Hand of (o) on the Scale, the Error is to be ſubſtracted from all Obſervations, otherwiſe to be added.

There is another Method of finding the Error of Adjuſtment, which ſeems rather preferable in point of Accuracy to the common Method juſt related. This conſiſts in meaſuring the apparent Diameter of any ſmall Object (as Jupiter's equatorial Diameter or the longeſt Axis of Saturn's Ring) with the Point (o) on the Vernier placed alternately to the Right Hand and Left of (o) on the Scale; only taking Care in the latter Caſe, inſtead of the Number ſhewn by the Vernier, to take its Complement to 25; Half the Difference of the Two Diameters thus found is the Error of the Adjuſtment, which is ſubſtractive or additive to all Obſervations, according as the Diameter meaſured with (o) of the Vernier advanced upon the Scale, or to the Right Hand of (o) on the Scale, is greater or leſs than the Diameter meaſured with (o) of the Vernier falling behind or to the Left of (o) on the Scale. It is evident that Half the Sum of the Two Diameters, as immediately given by the Meaſures of the Scale, is the true Diameter of the Object. This therefore is the juſt and proper Method of meaſuring the apparent Diameters of all the primary Planets. It is alſo the Method that ſhould be uſed in meaſuring the apparent Diameter of Venus on the Sun, eſpecially as it gives at the ſame Time the Error of the Adjuſtment, as juſt now explained.

The Error of the Adjuſtment may be taken away if required, by ſetting the Vernier to the Quantity of the Error found in Manner above-mentioned, and eaſing the Screw which fixes the Vernier to the Plate beneath it, and ſliding the Vernier till (o) thereon agrees exactly with (o) on the Scale; after which the Screw ſhould be tightened again. If the Error is large it ſhould be corrected, but if it be ſmall it may be as convenient to allow for it in the Obſervations.

The Third Point to be determined is the Value of the Scale of the Micrometer expreſſed in Minutes and Seconds. This may be found very readily and with ſufficient Exactneſs by meaſuring the Sun's horizontal Diameter, and comparing it with that given in the Nautical Almanac, or by Aſtronomical Tables, Allowance being made, as before directed, for the Error of the Adjuſtment. On the Day of the enſuing Tranſit of Venus the Sun's Diameter will be 31 Minutes and 31 Seconds, ſuppoſing the apogeal Diameter to be 31′. 28″, as was determined by Mr. *Short* with a Divided Achromatic Object-Glaſs, and it will be decreaſing at that Time at the Rate of 1 Second in 5 Days. Hence, if the horizontal Diameter be meaſured on the Day of the Tranſit, or within a Fortnight before or after it, the Value of One Extent of the Scale will be known in Minutes and Seconds; whence the Value of any other Extent may be found by Proportion, and a Table be made accordingly to facilitate the Reduction of the Obſervations. To find what the Sun's Diameter ſhould be at any Time of the Year, in Proportion to the apogeal Diameter aſſumed 31′. 28″, as above-mentioned, always ſubſtract 3″ from the Semidiameter given by the Nautical Almanac, or *Mayer*'s Tables, the Remainder doubled is the Diameter required. The Value of the Scale might alſo be determined, if thought neceſſary, by ſeveral other Methods independent of any Hypotheſis as that of the Sun's

Diameter. I ſhall only mention One, which is very ſimple, and perhaps as exact as any other. Adjuſt the Teleſcope without the Micrometer with great Care to diſtinct Viſion for the Planets Jupiter or Saturn, then put on the Micrometer, and find by ſeveral Trials the Diſtance at which a proper Object, ſuppoſe a printed Paper, ſhould be placed before the divided Object-Glaſs that it may appear moſt diſtinct through the Teleſcope, whoſe Adjuſtment muſt remain unaltered. This is the focal Length of the Object-Glaſs, and muſt be meaſured with great Care from the outer Surface of the Glaſs to the Object, to which, if you pleaſe, you may add One-third of the Thickneſs of the Glaſs, if double and equally convex. Then ſay, as this Sum is to any Extent of the Scale : : ſo is the Radius 100000: to twice the Tangent of Half the Angle anſwering to the Separation of the Glaſſes meaſured by that Extent of the Scale; or, in Practice, it may be ſufficiently exact if you ſay, as this Sum is to any Extent of the Scale (both being reduced to Meaſures of the ſame Denomination) ſo is 206265 Seconds, to a Number of Seconds contained in the Angle anſwering to the Separation of the Glaſſes meaſured by the propoſed Extent of the Scale; whence a Table of Reduction may readily be conſtructed.

The Inſtrument being thus prepared for Obſervation, let it be required to find by it at any Time the Diſtance of Venus from the Sun's Centre. This is to be done by meaſuring the Diſtance of Venus's exterior Limb from the neareſt Limb of the Sun, and the horizontal Diameters of the Sun and Venus; for the ſaid Diſtance ſubſtracted from the Difference of the Semidiameters gives the Diſtance of Venus's Centre from the Sun's Centre, which was required. This Obſervation if made at the Middle of the Tranſit will give the neareſt Approach of the Centres of the Sun and Venus: But the beſt Way will be to meaſure the actual Diſtance of the neareſt Limbs of the Sun and Venus, repeatedly, beginning ſome time before the neareſt Approach of the Centres, and continuing the Obſervation till that Time is paſt (which will appear by the Diſtance of Venus from the Sun's Limb, after becoming ſtationary, decreaſing) as well to be ſure of hitting the true Time, as to obtain the greater Certainty from taking a Mean of ſeveral Obſervations taken within a little Space of one another: It will be very expedient, ſoon after the neareſt Approach of Venus to the Sun's Centre has been meaſured and is paſt, to meaſure the Diameter of the Sun ſeveral Times in the ſame Direction, which will be effected near enough for the Purpoſe by uſing the Micrometer as left by the laſt Obſervation of the Diſtances; that if there is any Difference in the inclined Diameters of the Sun from the horizontal One, you may obtain the true leaſt Diſtance of the Centres of the Sun and Venus notwithſtanding; agreeable to a Hint of Mr. *Mallet*, Aſtronomer to the King of *Sweden*, at *Upſal*. Half the Sun's Diameter thus found leſſened by the Sum of the neareſt Diſtance of the Limbs of the Sun and Venus, and the Semidiameter of Venus, gives the true Diſtance of the Centres. In meaſuring other Diſtances than theſe about the Middle of the Tranſit, you may take the neareſt Diſtance of Venus from the Sun's Limb, the Sun's Diameter and Venus's, in order one after another; not forgetting however to obſerve the Sun's horizontal Diameter alſo, for determining the Scale of the Micrometer. In order to be ſure that you always take the Diſtance of Venus's Limb from the neareſt Part of the Sun's Circumference, turn the Micrometer round about by Means of the proper Handle, and Venus will apply herſelf ſucceſſively to different Parts of the Sun's Circumference; and when, during this Motion, ſhe is carried either parallel to the neareſt Part of the Sun's Circumference, or ſo as to continue to form a perfect internal Contact with the Sun's Limb for ſome Space, that is the proper Poſition of the Micrometer for meaſuring the Diſtance of the neareſt Limbs of Venus and the Sun: Therefore after this, as ſoon as poſſible, by ſeparating or bringing the Semicircles nearer to each other, cauſe Venus's Limb to form an accurate Contact with the Sun's Limb; then reading off the Numbers from the Scale you will have the

Meaſure of the Diſtance of Venus's near Limb from the Sun's. The Times ſhould be noted by the Clock, as uſual.

If ſeveral of theſe Obſervations are made during the Tranſit, the Path of Venus over the Sun may thereby be traced or calculated. Moreover, if ſome are taken not very far diſtant from the Time of the Contacts, they may enable us to find the ſaid Times by Calculation; ſuppoſing they could not be obſerved. It will however be proper to leave off theſe Meaſures when Venus is diſtant from the Sun's Limb by her whole Diameter, before the Second internal Contact, in order to prepare the Teleſcope for the ſame, by taking off the Micrometer and adjuſting the Teleſcope without it to diſtinct Viſion. If there is not much Time to ſpare before the Contact, it will be better to adjuſt the Teleſcope by Means of the Scale and Vernier placed on the Side of it, according to Experiments made before by looking at the Sun. It will indeed be highly proper to ſettle the Adjuſtment of the Teleſcope by ſeveral Trials, both without the Micrometer, and with the Micrometer applied to it, ſome time before the Day of the Tranſit, and to note down the Numbers of the Vernier on the Side of the Teleſcope, or make Marks on the Eye-Tube, whereby the Teleſcope may be re-adjuſted at once to its proper Focus, according as the Micrometer is applied to it or not.

It will be alſo very proper to prepare the Inſtruments for Uſe in every Reſpect ſome Days before the Tranſit; and try them on the Sun on the very Day before the Tranſit, and at the ſame Hours on which Venus will appear the next Day upon the Sun, that if there are any Defects in the Apparatus of the Inſtruments, or any local Obſtacles to the Uſe of them, ariſing from the Poſition of the Sun, or Inconveniencies of the Place, they may be removed in time.

It will be highly proper for the Obſervers, who attend the enſuing Tranſit of Venus, to make other Obſervations, in order to determine the Latitudes and Longitudes of the Places where they are ſtationed. For finding the Latitude they ſhould take Meridian Altitudes of the Sun, and alſo of Stars both to the North and South of the Zenith. For ſettling the Longitude they may obſerve any of the following celeſtial Phænomena, or as many of different Kinds as the Inſtruments they may be furniſhed with and other Circumſtances may permit; for the nearer this Point is determined the more uſeful and valuable will their Obſervations of the Tranſit prove.

1. Eclipſes of the Sun and Moon.

2. Immerſions and Emerſions of Jupiter's Satellites; but principally of the Firſt Satellite.

3. Occultations of fixed Stars and Planets by the Moon's Limb, and their Emerſions from the ſame.

4. Differences of Right Aſcenſion between the Moon's enlightened Limb and Stars lying near her Parallel of Declination, by Means of moveable Wires placed in the Focus of a Teleſcope.

5. Tranſits of the Moon's enlightened Limb over the the Meridian compared with the Tranſits of the principal Stars of the Firſt and Second Magnitude lying neareſt to the Equator.

6. Correſponding Altitudes of the Moon's upper or lower Limb compared with correſponding Altitudes of fixed Stars.

7. Altitudes of the Moon's upper or lower Limb, when ſhe is upon or near the Meridian, and her Declination varies at leaſt 3 Degrees in 24 Hours. The Time of the Obſervation ſhould be noted by the Clock, and Meridian Altitudes of fixed Stars near the Moon's Parallel of Declination ſhould be alſo obſerved, if convenient, before or after the Moon's Tranſit.

8. The internal and external Contacts of the Planet Mercury with the Sun's Limb, whenever he paſſes over the Sun. An Opportunity of this Kind will happen on *Nov.* 9, 1769. The Ingreſs will happen at 7 h. 40 m. and the Egreſs at 12 h. 32 m. apparent Time by the Meridian of *Greenwich*. This Tranſit will be principally viſible in *America*.

The 5th, 6th, and 7th Methods are peculiarly adapted for the Uſe of thoſe Aſtronomers who ſhall obſerve the enſuing Tranſit of Venus in high Northern Latitudes; as they may be obſerved with proper Inſtruments, notwithſtanding the perpetual Day which will then reign at thoſe Places, and which will deprive them of the Benefit of almoſt every other celeſtial Phænomenon. It may be proper to remark, that in the Uſe of the 6th Method it will often happen that the Altitude of the Moon's upper Limb muſt be taken on One Side of the Meridian, and the Altitude of her lower Limb on the other Side; but the Quadrant muſt be ſet to the ſame Altitude for both Obſervations.

Thoſe who propoſe to obſerve the enſuing Tranſit of Venus over the Sun will do well to make themſelves expert in the Uſe of all their Inſtruments, as applied to all the different Kinds of Obſervation, before the Tranſit happens; and, if they have not been much verſed in Aſtronomical Calculations, they need not be ſolicitous to reduce their Obſervations of the Tranſit and other Phænomena to Time, but had better ſend their original Obſervations, with all their Circumſtances, to the Royal Society, or ſome learned and ſkilful Aſtronomer, who may afterwards deduce the proper Conſequences from them, at Leiſure. Two general Tables are here added, taken from Mr. *De Lalande*'s Aſtronomy, for computing the Equation of correſponding Altitudes to any Latitude. The Uſe of them is as follows:

On account of the Sun's Change of Declination, the middle Time between the equal Altitudes of the Sun obſerved in the Morning and in the Aftetnoon is not the true Time of Noon, except on the Days of the Two Solſtices, and is therefore to be corrected by an Equation, commonly called by the Title of that of Correſponding Altitudes, which is here given by the Sum or Difference of Two Tables. Subſtract the Time ſhewn by the Clock at the Altitude obſerved in the Morning, from that ſhewn by the Clock at the Altitude obſerved in the Afternoon, increaſed by 12 Hours, and you will have the Interval between the Obſervations according to the Clock; take its Half, and add it to the obſerved Time of the Altitude in the Morning, and you will have the Time of Noon by the Clock, but uncorrect. Then enter the Firſt Table, or Part I. of the general Equation with the Sun's Longitude at Noon on the Side, and Half the Interval of the Obſervations at the Top of the Table, and take out the Number which ſtands at the common Meeting of the horizontal and vertical Lines (making a Proportion, if neceſſary) and note whether it is additive or ſubſtractive. In like manner take a Number out of the Second Table, or Part II. of the general Equation, which multiply by the natural Tangent of the Latitude (to the Radius Unity) and note whether it is additive or ſubſtractive by the Table, which is ſuited to a Northern Latitude; but if the Latitude be South, for ſubſtract read add, and for add read ſubſtract: Laſtly, If the Two Numbers thus found are both of the ſame Kind, viz. both additive or both ſubſtractive, take their Sum, and apply it with the common Title or Sign to the Time of Noon uncorrect; but if the Numbers are of different Kinds, viz. one additive, and the other ſubſtractive, take the Difference, and apply it with the Sign of the greater of the Two to the Time of Noon uncorrect, and you will have the true Time of Noon by the Clock, or the Time ſhewn by the Clock at the Inſtant of the Sun's Centre paſſing the Meridian.

EXAMPLE.

Suppoſe that equal Altitudes of the Sun's upper Limb ſhould be taken on the 3d of *June* 1769, in Latitude 58° 56′ N. and in Longitude 6h. 19m. 40ſ. to the Weſt of *Greenwich*, at 8 h. 14 m. 8 ſ. in the Morning, and 3 h. 42 m. 38 ſ. in the Afternoon by the Time of a Clock; let it be required to find the Time of Noon by the Clock. To 3 h. 42 m. 38 ſ. add 12 h. and from the Sum ſubſtract 8 h. 14 m. 8 ſ. the Remainder is 7 h. 28 m. 30 ſ. and its

Half, 3 h. 44 m. 15 ſ. is the Half Interval between the Obſervations, which added to 8 h. 14 m. 8 ſ. gives 11 h. 58 m. 23 ſ. for the Time of Noon uncorrect. The Sun's Longitude at Noon at the given Place, or at 6 h. 19 m. 40 ſ. after Noon at *Greenwich,* will be 2^{s}. 13°. 18′. with which and the Half Interval, 3 h. 44 m. 15 ſ. you will find by the Firſt Table the Number + 1,20 ſ. or additive, and by the Second Table — 5,31 ſ. but this latter Quantity is to be multiplied by the Tangent of the Latitude 58°. 56′ or by 1,66, whence the Number deduced from the Second Table is — 8,81, or ſubſtractive. The Difference of 1,20″ and 8,81, becauſe one is additive and the other ſubſtractive is — 6,61, or ſubſtractive for the Equation of the correſponding Altitudes, becauſe the ſubſtractive Quantity is greateſt; therefore 6,61 ſubſtracted from 11 h. 58′ 23″ leaves 11 h. 58 m. 16,4 ſ. for the true Time of Noon. If the Latitude be ſuppoſed 58° 56′ South, inſtead of North, and the Half Interval between the Obſervations, 2 h. 20 m. the Firſt Part of the Equation would be + 1,60 or additive, and the Second Part, as taken out of the Table, — 4,81 or ſubſtractive, which multiplied by 1,66, the Tangent of the Latitude, and changing the Sign, becauſe the Latitude is South, becomes + 7,98 ſ. or additive, as well as the Firſt Part; therefore the Sum of the Two, viz. 1,60 ſ. and 7,98 ſ. equal to + 9,58, is the Equation of correſponding Altitudes to be added to the middle Time between the Obſervations.

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A General TABLE of the Equation of correſponding Altitudes.

PART I.

Half the Interval between the Obſervations.

Longit. ⊙		1h 40′	2h 0′	2h 20′	2h 40′	3h 0′	3h 20′	3h 40′	4h 0′
Ↄ	0	0″00	0″00	0″00	0″00	0″00	0″00	0″00	0″00
add	10	0, 96	0, 93	0, 89	0, 85	0, 80	0, 75	0, 69	0, 62
	20	1, 89	1, 76	1, 69	1, 61	1, 53	1, 43	1, 30	1, 17
I	0	2, 49	2, 41	2, 32	2, 21	2, 09	1, 95	1, 79	1, 61
add	10	2, 90	2, 81	2, 70	2, 58	2, 43	2, 27	2, 08	1, 87
	20	2, 97	2, 88	2, 77	2, 64	2, 49	2, 32	2, 13	1, 92
II	0	2, 68	2, 59	2, 50	2, 38	2, 25	2, 09	1, 92	1, 73
add	10	2, 02	1, 96	1, 89	1, 80	1, 70	1, 58	1, 45	1, 31
	20	1, 10	1, 06	1, 02	0, 97	0, 92	0, 86	0, 79	0, 71
III	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
ſubſtr.	10	1, 10	1, 06	1, 02	0, 97	0, 92	0, 86	0, 79	0, 71
	20	2, 02	1, 96	1, 88	1, 79	1, 70	1, 58	1, 45	1, 31
IV	0	2, 66	2, 58	2, 48	2, 37	2, 24	2, 08	1, 91	1, 72
ſubſtr.	10	2, 94	2, 85	2, 74	2, 62	2, 47	2, 30	2, 11	1, 90
	20	2, 87	2, 78	2, 68	2, 56	2, 41	2, 25	2, 06	1, 86
V	0	2, 47	2, 40	2, 31	2, 20	2, 08	1, 94	1, 78	1, 60
ſubſtr.	10	1, 81	1, 75	1, 68	1, 60	1, 52	1, 32	1, 29	1, 16
	20	0, 95	0, 92	0, 89	0, 85	0, 80	0, 74	0, 68	0, 61
VI	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
add	10	0, 96	0, 93	0, 89	0, 85	0, 80	0, 75	0, 69	0, 62
	20	1, 84	1, 78	1, 72	1, 65	1, 56	1, 46	1, 24	1, 20
VII	0	2, 55	2, 47	2, 38	2, 27	2, 14	2, 00	1, 83	1, 65
add	10	3, 00	2, 91	2, 80	2, 67	2, 52	2, 35	2, 15	1, 94
	20	3, 10	3, 01	2, 89	2, 76	2, 61	2, 43	2, 23	2, 01
VIII	0	2, 83	2, 74	2, 64	2, 52	2, 38	2, 21	2, 03	1, 83
add	10	2, 15	2, 08	2, 00	1, 91	1, 80	1, 68	1, 54	1, 39
	20	1, 17	1, 13	1, 09	1, 04	0, 98	0, 91	0, 84	0, 75
IX	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
ſubſtr.	10	1, 17	1, 13	1, 09	1, 04	0, 98	0, 91	0, 84	0, 75
	20	2, 15	2, 09	2, 01	1, 92	1, 81	1, 69	1, 55	1, 39
X	0	2, 84	2, 76	2, 64	2, 56	2, 39	2, 22	2, 04	1, 84
ſubſtr.	10	3, 13	3, 03	2, 91	2, 78	2, 62	2, 45	2, 25	2, 02
	20	3, 02	2, 93	2, 82	2, 69	2, 54	2, 37	2, 16	1, 95
XI	0	2, 57	2, 49	2, 40	2, 29	2, 16	2, 01	1, 85	1, 66
ſubſtr.	10	1, 86	1, 80	1, 73	1, 65	1, 56	1, 46	1, 33	1, 20
	20	0, 97	0, 94	0, 90	0, 86	0, 81	0, 76	0, 69	0, 63

A General TABLE of the Equation of correſponding Altitudes.

PART II.

Half the Interval between the Obſervations.

Longit. ☉		$1^h\ 40'$	$2^h\ 0'$	$2^h\ 20'$	$2^h\ 40'$	$3^h\ 0'$	$3^h\ 20'$	$3^h\ 40'$	$4^h\ 0'$
○	0	15″53	15″78	16″09	16″37	16″74	17″17	17″66	18″23
ſubſtr.	10	15, 25	15, 50	15, 80	16, 08	16, 44	16, 86	17, 35	17, 91
	20	14, 56	14, 80	15, 09	15, 35	15, 70	16, 10	16, 56	17, 10
I	0	13, 49	13, 71	13, 97	14, 22	14, 54	14, 91	15, 34	15, 83
ſubſtr.	10	12, 03	12, 23	12, 47	12, 69	12, 97	13, 30	13, 69	14, 13
	20	10, 20	10, 37	10, 57	10, 76	11, 00	11, 28	11, 61	11, 98
II	0	8, 02	8, 15	8, 31	8, 45	8, 64	8, 86	9, 12	9, 41
ſubſtr.	10	5, 58	5, 62	5, 73	5, 83	5, 96	6, 12	6, 29	6, 50
	20	2, 82	2, 87	2, 93	2, 98	3, 05	3, 12	3, 21	3, 32
III	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
add	10	2, 82	2, 87	2, 92	2, 97	3, 04	3, 12	3, 21	3, 31
	20	5, 51	5, 60	5, 71	5, 81	5, 95	6, 10	6, 27	6, 48
IV	0	7, 98	8, 11	8, 27	8, 41	8, 60	8, 82	9, 08	9, 37
add	10	10, 11	10, 28	10, 48	10, 66	10, 90	11, 18	11, 51	11, 88
	20	11, 94	12, 17	12, 37	12, 59	12, 87	13, 20	13, 58	14, 02
V	0	13, 37	13, 59	13, 85	14, 10	14, 41	14, 78	15, 21	15, 70
add	10	14, 42	14, 66	14, 94	15, 20	15, 55	15, 94	16, 41	16, 93
	20	15, 09	15, 34	15, 64	15, 92	16, 27	16, 69	17, 17	17, 72
VI	0	15, 37	15, 63	15, 93	16, 21	16, 58	17, 00	17, 49	18, 05
add	10	15, 26	15, 52	15, 81	16, 09	16, 46	16, 87	17, 36	17, 92
	20	14, 75	15, 00	15, 29	15, 56	15, 91	16, 31	16, 78	17, 32
VII	0	13, 82	14, 05	14, 32	14, 57	14, 90	15, 28	15, 74	16, 23
add	10	12, 46	12, 66	12, 91	13, 14	13, 43	13, 78	14, 17	14, 63
	20	10, 76	10, 84	11, 05	11, 25	11, 50	11, 80	12, 14	12, 53
VIII	0	8, 46	8, 59	8, 76	8, 91	9, 12	9, 35	9, 62	9, 93
add	10	5, 87	5, 83	6, 08	6, 19	6, 33	6, 49	6, 63	6, 89
	20	3, 01	3, 06	3, 12	3, 18	3, 25	3, 33	3, 43	3, 54
IX	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
ſubſtr.	10	3, 02	3, 07	3, 13	3, 18	3, 25	3, 34	3, 43	3, 54
	20	5, 89	6, 00	6, 10	6, 36	6, 50	6, 67	6, 86	6, 92
X	0	8, 42	8, 64	8, 80	8, 96	9, 16	9, 39	9, 67	9, 98
ſubſtr.	10	10, 74	10, 91	11, 12	11, 32	11, 58	11, 90	12, 21	12, 61
	20	12, 56	12, 77	13, 01	13, 24	13, 54	13, 88	14, 29	14, 74
XI	0	13, 94	14, 17	14, 45	14, 70	15, 03	15, 41	15, 86	16, 37
ſubſtr.	10	14, 90	15, 14	15, 43	15, 71	16, 06	16, 47	16, 94	17, 48
	20	15, 37	15, 63	15, 93	16, 21	16, 57	17, 00	17, 49	18, 05

Multiply by the Tangent of the Latitude; and if it is South, change the Signs.

Apparent Times of the external and internal Contacts of VENUS with the Sun's Limb at ſeveral Places, as they may be expected to happen on June the 3d 1769.

	1ſt ext. cont.		1ſt int. cont.		2d int. cont.		2d ext. cont.		Latitude.			Suppoſed Longitude from Greenw			
	h.	m.	h.	m.	h.	m.	h.	m.				h.	m.	ſ.	
Greenwich	7	6	7	25	—		—		51	29	N	0	0		
Edinburg	6	53	7	12	—		—		55	58	N	0	13	13	W
Dublin	6	41	7	0	—		—		53	20	N	0	24	54	W
Tornea	8	43	9	2	14	56	15	15	65	51	N	1	36	48	E
Kittis	8	43	9	2	14	56	15	15	66	48	N	1	36	48	E
Attengaard	8	39	8	58	14	51	15	10	69	59	N	1	32	27	E
Wardhus	9	12	9	31	15	24	15	43	70	35	N	2	5	36	E
North Cape	8	51	9	10	15	3	15	22	71	23	N	1	44	48	E
Bear Iſland	8	12	8	31	14	24	14	43	74	32	N	1	5	36	E
Spitzbergen, Bell-Sound	7	57	8	16	14	8	14	27	77	15	N	0	51	2	E
Peterſberg	—		—		15	21	15	40	59	56	N	2	1	20	E
Tobolſki	—		—		17	53	18	12	58	12	N	4	32	51	E
S. John's, Newfoundland	3	40	3	59	—		—		47	32	N	3	31	13	W
Quebec	2	29	2	48	—		—		46	55	N	4	39	36	W
Hudſon's Bay	0	49	1	8	6	54	7	13	58	56	N	6	19	40	W
Boſton	2	26	2	45	—		—		42	25	N	4	42	29	W
Williamſberg	2	3	2	22	—		—		37	20	N	5	6	20	W
Jamaica, Port Royal	2	4	2	23	—		—		18	0	N	5	7	2	W
Mexico	0	19	0	38	6	14	6	33	20	0	N	6	54	40	W
Cape Corientes	23*	48	0	6	5	44	6	3	20	50	N	7	25	40	W
Cape St. Lucar	23*	31	23*	50	5	28	5	47	23	15	N	7	41	40	W
Cape Conception	22*	34	22*	53	4	33	4	52	35	30	N	8	37	40	W
Fernambuca, Brazil	4	50	5	9	—		—		8	13	S	2	20	8	W
Conception, Chili	2	24	2	43	—		—		36	43	S	4	50	44	W
Bombay	—		—		18	9	18	28	19	18	N	4	47	48	W
Madraſs	—		—		18	41	19	0	13	13	N	5	20	9	E
Calcutta	—		—		19	14	19	33	22	30	N	5	53	43	E

N. B. The Contacts marked with Aſteriſks belong to the 2d Day of June 1769, according to Aſtronomical Time.

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